Section 1
INTRODUCTION

From 1942 to 1946, portions of the Linde Site in the Town of Tonawanda, New York, were used for separation of uranium ores. These processing activities and supporting pilot laboratory studies, which were conducted under contract with the Manhattan Engineer District (MED), resulted in radioactive contamination of portions of the property and buildings, including Building 14 at the Linde Site. Subsequent disposal and relocation of processing wastes from the Linde Site also resulted in radioactive contamination of three nearby properties in the Town of Tonawanda: Ashland 1, Ashland 2, and the Seaway Industrial Park. Together these four properties are referred to as the Tonawanda Site.

The U.S. Army Corps of Engineers (USACE) is conducting cleanup of the Tonawanda Site, including the Linde Site, under the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established to identify and clean up or otherwise control sites where residual radioactive contamination remains from the early years of the nation's atomic energy program. During 1988–92, remedial investigation was conducted to determine the nature, extent, and potential for migration of the radioactive and associated chemical contamination resulting from MED operations. Based on the results of the remedial investigation and several subsequent selective investigations, an extensive decontamination effort was undertaken in Building 14 during 1996–98 to prevent the potential for occupational exposure to the current or future tenants.

1.1 PURPOSE

This post-remedial action report (PRAR) documents the remedial action performed by USACE inside Building 14 at the Linde Site. Under FUSRAP, the remedial action was designed to address residual radioactive contamination and associated chemical contamination in the building as a result of previous MED operations conducted during the 1940s. The PRAR demonstrates that remediation was performed in accordance with applicable regulatory guidance and that the interior of the building was decontaminated to acceptable levels such that it may be released without radiological restrictions. Elements of the PRAR include (1) a summary of site history, previous investigations, and regulatory authority; (2) derivation of cleanup guidelines and criteria; (3) discussion of the general approach and methodologies used for delineation, decontamination, and verification of the contaminated areas; and (4) specific information concerning each remediation zone, including the extent and range of residual contamination. Additional information supporting the successful remediation of Building 14 is included in appendixes to this document. Appendixes A through E contain information regarding the data collected by the remediation subcontractor, IDM, Inc. Appendix F contains the *Summary Report for the Process Piping Radiological Investigation, Praxair Building 14*. Appendix G is a compilation of letters from the independent verification contractor [Oak Ridge National Laboratory (ORNL)] verifying the successful remediation of each area within Building 14. Appendix H contains surveys that were used as verification surveys for the sump and drainlines in the Area 12 stairwell. Appendix I contains photographs of general interest, showing various aspects of the remediation effort. Appendix J contains the comments received on the draft PRAR.

1.2 BACKGROUND

This section presents background information on the regulatory authority for FUSRAP and the history of the Linde site.

1.2.1 Regulatory Authority Under FUSRAP

In 1974, the United States Congress authorized the Atomic Energy Commission (AEC), a predecessor of the U.S. Department of Energy (DOE), to institute FUSRAP. The goals of FUSRAP are to control radioactive and associated chemical contamination at its sites, maintain the sites in compliance with applicable criteria for the protection of human health and the environment, and certify the sites for use without radiological restrictions following decontamination.

The authority to remediate the Linde Site was provided under the Atomic Energy Act of 1954 (42 USC 2001 et seq., Public Law 703, 83rd Congress, 68 Stat. 919, as amended). In February 1980, the Linde property was designated for remedial action under FUSRAP. In October 1997, management of FUSRAP was transferred from DOE to USACE, and USACE assumed responsibility for:

- Managing radioactive contamination related to MED processing and management of radioactive materials at the Linde Site.

- Managing any chemical contamination at the Linde Site that is mixed with radioactive contamination or that resulted from activities conducted for MED.

USACE assumes no responsibility for identifying or remediating chemical contamination that is not related to MED activities.

Under DOE Order 5400.5, the remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS) process was initiated to meet the procedural and documentation requirements of the National Environmental Policy Act (NEPA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for obtaining sufficient information on the nature and extent of contamination at the Tonawanda Site to support the evaluation of remedial action alternatives. DOE Order 5400.4 required that any response to releases or potential imminent releases will be conducted in accordance with CERCLA, the National Oil and Hazardous Substances Pollution Contingency Plan, and Executive Order 12580. Additionally, the order required that where CERCLA remedial actions trigger NEPA procedures, the procedural and documentation requirements of CERCLA and NEPA will be integrated, whenever practical. Following the transfer of FUSRAP from DOE to USACE, USACE is satisfying the requirements of NEPA through the CERCLA process. Actions at the Tonawanda Site were coordinated with the New York State Department of Environmental Conservation (NYSDEC) and the U.S. Environmental Protection Agency (EPA) Region II under CERCLA, as amended by the Superfund Amendments and Reauthorization Act.

1.2.2 Site History

In the 1940s and 1950s, MED and AEC conducted a research and development program involving the processing of radioactive materials, with most of the work performed by private contractors on privately owned sites. One such site was the Linde Air Products Corporation in Tonawanda, New York (Figure 1-1). Linde was selected because of the company's experience in the ceramics business, which involved processing uranium to produce salts used to color ceramic glazes. From 1942 through 1946, uranium from seven different sources was processed at Linde under the MED contract: four African ores (three low-grade pitchblendes and a torbernite) and three domestic ores (carnotite from Colorado). Five Linde buildings, shown in Figure 1-2, were involved in MED activities, including Building 14 (built by Union Carbide in the mid-1930s) and Buildings 30, 31, 37, and 38 (built by MED on land owned by Union Carbide). Ownership of Buildings 30, 31, 37, and 38 was transferred to Linde when the MED contract was terminated.

During the early uranium operations, Building 14 was used primarily as a research laboratory and pilot plant to support full-scale operations being conducted at the other MED buildings. Historical drawings indicate that the MED laboratory and pilot plant studies were initially confined to the south part of the building. It is unclear how extensively the remainder of the building was used for MED operations. However, documents indicate that laboratory and pilot plant operations were continued for the purpose of experimenting and developing more efficient processing methods, and operations appear to have been expanded into most of the building, possibly to support larger pilot studies. It is assumed that the building continued to be used until the end of MED operations at the Linde Site in 1946.

1.2.3 Process Description

Substantial information exists regarding the full-scale process conducted at the Linde Site; however, information on specific activities conducted in Building 14 during pilot studies is limited. It is reasonable to assume that processes similar to those described for the full-scale production occurred during the pilot studies on a smaller scale.

A three-phase process was used to separate uranium from the uranium ores and tailings. Phase I consisted of separating triuranium octoxide (U_3O_8) from the feedstock materials by a series of process steps consisting of acid digestion, precipitation, and filtration. The filtrate (liquid remaining from the processing operations) from this step was discarded as liquid waste into the injection wells, storm sewers, or sanitary sewers. The filter cake was discarded as solid waste and ultimately taken to Ashland 1. The triuranium octoxide from Phase I was processed into uranium dioxide (UO_2) during Phase 2. In Phase 3, the uranium dioxide was converted to uranium tetrafluoride (UF_4). Residues from Phases 2 and 3 were reprocessed (Aerospace 1981).

Because the first phase of uranium processing operations was the source of the waste, that phase is examined in detail to provide a description of the types of waste that were produced. Figure 1-3 is a flow diagram of Phase 1, which consisted of the following steps:

1. Sulfuric acid was added to the ore slurry until the pH of the mixture reached 0.7 to 0.8. All components of the ores (radioactive and chemical) became partially dissolved during this acid extraction process.
2. Pyrolucite or braunite was added to the ore slurry solution to oxidize any reduced uranium present.
3. The solution was digested at 90°C (194°F) for 3 hours.

4. After the digestion process was completed, the solution was cooled with a weak wash solution at 60°C (140°F). At this point, the uranium was in solution as uranyl sulfate.
5. After the solution cooled, soda ash was added until the solution reached a pH of 9.2.
6. At this point, sodium bicarbonate was added to the solution. This step precipitated most of the impurities and left the uranium in solution as sodium uranyl tricarbonate.
7. The solution was filtered with Moore filters. The resulting residues were considered solid waste and were placed in a temporary tailings pile north of Buildings 30, 38, 39, and 58.
8. The procedure used for the next task depended on the type of ore being processed. If the ore was domestic, ferrous and ferric sulfates were added to remove the vanadium and phosphorus. If the ore was of African origin, barium chloride was added to remove the radium.
9. For the domestic ores, the resultant iron cake residues were filtered off in plate and frame presses and taken to a temporary tailings pile north of Buildings 30, 38, 39, and 58.
10. The liquors were treated with caustic soda, causing precipitation of the uranium as sodium diuranate. The filtrate was discharged as waste effluent into the sanitary sewers, storm sewers, or onsite disposal wells.
11. The sodium diuranate cake from Step 10 was treated with sulfuric acid and ammonium sulfate to produce an ammonium uranyl sulfate complex.
12. The ammonium uranyl sulfate complex was removed in a filter press and fed to a calciner to drive off the ammonia, sulfur dioxide, sulfur trioxide, and water, leaving uranium oxide to be processed in Phase 2.

The principal solid waste resulting from Phase I was a solid, gelatinous filter cake consisting of impurities remaining after filtration of the uranium carbonate solutions. Phase I also produced insoluble precipitates of the dissolved constituents, which were combined with the tailings. The precipitated species included large quantities of silicon dioxide, iron hydroxide, calcium hydroxide, calcium carbonate, aluminum hydroxide, lead sulfate, lead vanadate, barium sulfate, barium carbonate, magnesium hydroxide, magnesium carbonate, and iron complexes of vanadium and phosphorus (Aerospace 1981).

1.2.4 Previous Investigations and Remedial Actions

Prior to the remedial investigation, two radiological surveys were performed in Building 14 at the Linde Site to determine whether radioactive contaminants were present at levels above existing guidelines. The first survey was conducted by ORNL during October and November 1976 (ORNL 1978). The survey included measurements of residual alpha (α) and beta/gamma (β/γ) contamination levels, external γ levels at 1 meter (3 feet) above the surface, and radon and radon daughter concentrations in the air. Direct readings of α contamination were taken on the floors throughout the building and in the utility tunnel (284 locations), and selected measurements were taken on the walls, ceilings, and supports. Direct α readings were found to exceed 100 dpm/100 cm^2 at 30 locations (readings ranged from 100 to 800 dpm/100 cm^2). The elevated readings were mainly found in the corridor, large hallway, and Area 12. Beta/gamma dose rates exceeded 0.20 mrad/hr at 15 locations (readings ranged from 0.23 to 4.0 mrad/hr). The maximum β/γ reading was collocated with the highest direct α reading at the bottom of the stairway in Area 12 leading to the utility tunnel. Measurements of external γ radiation levels at 1 meter (3 feet) above the floor ranged from 6 to 25 μR/hr. Radon daughter concentrations taken at three locations in the building were measured at 0.001 working level (WL). (A WL is any combination of short-lived radon decay products in 1 L of air that will result in the ultimate emission of 1.3×10^5 MeV of potential energy.)

Based on the results of this survey, which indicated contamination of the interior surfaces of Building 14, the property owner decontaminated the building in 1980 by removing the contaminated cement flooring and cement wall surfaces until levels below twice the background level were reached.

In December 1981, a second survey was conducted by Ford, Bacon, & Davis Utah, Inc. (FBDU) to determine residual levels of radioactive contamination. The survey measured residual α and β/γ contamination levels; external γ radiation levels at 1 meter (3 feet) above the surface; radon and radon daughter concentrations in the air; and uranium-238, radium-226, and thorium-232 concentrations in onsite soils. The maximum external γ radiation reading from this survey was 20 μR/hr, including background. The maximum observed direct (fixed) α contamination level was 120 dpm/100 cm^2. Transferable α contamination was less than 20 dpm/100 cm^2 throughout the building, and β/γ contamination at all locations was less than 0.2 mrad/hr. Radon daughter concentrations were less than 0.015 WL.

Under the authority of FUSRAP, Building 14 was resurveyed during remedial investigation activities conducted in 1988-92 at the Tonawanda Site. Because the building was believed to be uncontaminated, the investigation consisted of confirmatory sampling, which included the collection of dust and dirt samples from inaccessible areas, random direct contact α and β/γ measurements on the floors and walls, and random smear samples. Fixed-point β/γ measurements ranged from less than 720 to 278,420 dpm/100 cm^2. All readings that exceeded guidelines were taken on the first floor in the center of the building where the tile and carpet had been removed. The highest reading was at the bottom of the staircase between the upper and lower levels of the first floor. Survey results indicate that most of the first floor contained fixed residual radioactivity exceeding DOE guidelines. A sample of dust from the basement stairwell contained 590 pCi/g of uranium-238, 0.4 pCi/g of radium-226, and less than 1.0 pCi/g of thorium-230. This confirmed the direct readings and indicated the presence of radioactive contamination in the building.

1.2.5 Designation of the Property

In February 1980, DOE determined that portions of the Linde Air Products facility (formerly Linde Uranium Refinery) were contaminated with radioactive residue as a result of activities of MED and AEC. Although the Linde Site was considered a low priority, this determination indicated the need for some form of remedial action.

1.3 REMEDIAL ACTION GUIDELINES

Cleanup of residual radioactive material and management of the resulting wastes and residues at the Linde Site were performed in accordance with DOE Order 5400.5, “Radiation Protection of the Public and the Environment.” DOE Order 5400.5 establishes regulatory guidance on radiation protection of the public and the environment from (1) residual concentrations of radionuclides in soil, (2) concentrations of airborne radon decay products, (3) external γ radiation, (4) surface contamination, and (5) radionuclide concentrations in air or water resulting from or associated with any of the above. The attainment of these criteria and standards allows release of a property without radiological restrictions or determines completion of remedial action.

Guidelines for residual concentrations of thorium and radium in soil, concentrations of airborne radon decay products, allowable indoor external γ radiation levels, and residual surface contamination concentrations are based on existing radiological protection standards (DOE Order 5400.5). Guidelines for residual concentrations of other radionuclides in soil are derived from the basic dose limits by means of an environmental pathway analysis, using specific property data where available. The use of these guidelines established by DOE was continued after FUSRAP was transferred to USACE because the remedial action was already in progress at that time.

1.3.1 Primary Contaminants

Based on historical records and results of the remedial investigation, the residual radioactive contamination at the Linde Site resulted from the uranium ore processing operations. Although there are radionuclides from three distinct decay chains within these ores (uranium-238, uranium-235, and thorium-232), historical ore assaying as well as natural uranium isotopic abundance and characterization data indicate that radionuclides associated with the uranium-238 chain are the primary radiological constituents of concern. No enrichment activities were conducted at Linde; therefore, radionuclides associated with the actinium decay series (uranium-235 decay chain) are not of concern because the maximum activity due to uranium-235 would be less than 3% of the total activity. The amount of natural thorium (thorium-232) in these ores is minimal. (The average concentration of thorium-232 at Linde is 1.4 pCi/g. Natural background for the area is 1.2 pCi/g.)

1.3.2 Generic Guidelines and Site-Specific Criteria

The DOE guideline for residual radioactive material is a level of radioactive material that is acceptable for use of a property without restrictions because of residual radioactive material. The guidelines and site-specific criteria are described in the following sections and are summarized in Table 1-1.

1.3.2.1 Soil Criteria

The guideline for residual concentrations of uranium was derived from the basic dose limit by means of an environmental pathway analysis performed by Argonne National Laboratory (ANL) using specific property data. The supporting ANL analysis determined that a maximum of 77 pCi/g to 4,200 pCi/g of residual total uranium in soil is equivalent to 100 mrem per year, depending on future land use. Consequently, a guideline of 60 pCi/g above background was recommended based on the most conservative land use scenario (DOE 1992). This is equivalent to approximately 3 mrem per year for an industrial worker and less than 2 mrem per year for recreational purposes. Although considered an unlikely scenario, the recommended guideline for subsistence residential use results in an annual exposure of 78 mrem per year.

DOE Order 5400.5 generic guidelines established for residual concentrations of radium-226, radium-228, thorium-230, and thorium-232 in soil are:

- 5 pCi/g above background, averaged over the first 15 cm of soil below the surface; and
- 15 pCi/g above background, averaged over each 15-cm-thick layer of soil more than 15 cm below the surface.

These guidelines take into account ingrowth of radium-226 from thorium-230 and of radium-228 from thorium-232 and assume secular equilibrium. The guidelines are summarized in Table 1-1, and the background concentrations for radiological constituents for the Linde Site are presented in Table 1-2.

1.3.2.2 Surface Contamination

The DOE Order 5400.5 generic surface contamination guidelines provided in Table 1-1 are applicable to existing structures and equipment. These limits apply to both interior equipment and building components that are potentially salvageable or recoverable scrap. For the Linde Site, where radionuclides associated with the uranium-238 chain are the primary radiological constituents of concern, uranium-238 and other alpha-emitting radionuclides are limited to residual surface contamination levels of 15,000 dpm/cm^2, 5,000 dpm/cm^2, and 1,000 dpm/cm^2 for maximum, average, and removable contamination, respectively. Beta/gamma-emitting radionuclides are limited to the same levels of residual surface contamination, but the limits are implemented independently of alpha-emitting radionuclide levels.

1.3.2.3 External Gamma Radiation

The average level of γ radiation inside a building or habitable structure on a site to be released without radiological restrictions must not exceed the background level by more than 20 μR/hr and must comply with the basic dose limit when an “appropriate-use” scenario is considered.

1.3.2.4 Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products are applicable to existing occupied or habitable structures on private property that are intended for release without radiological restriction. The applicable generic guideline (40 CFR Part 192) is as follows: *“In any occupied or habitable building, the objective of remedial action shall be, and a reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL.”*

1.3.3 Supplemental Limits Approach

DOE Order 5400.5 states that if specific property circumstances indicate that the guidelines or authorized limits established for a given property are not appropriate for any portion of that property, then supplemental limits or an exception may be requested. The application for such exceptions should document the decision that the subject guidelines or authorized limits are not appropriate and that the alternative action selected will provide adequate protection, giving due consideration to health and safety, the environment, costs, and public policy considerations.

Supplemental limits must achieve the basic dose limits for both current and potential unrestricted uses of a property. Supplemental limits may be applied to any portion of a property if, on the basis of a specific property analysis, it is determined that (1) certain aspects of the property were not considered in the development of the established authorization limits for that property, and (2) as a result of these certain aspects, the established limits either do not provide adequate protection or are unnecessarily restrictive and costly.

The need for supplemental limits and exceptions must be documented on a case-by-case basis using specific property data. Every reasonable effort is made to minimize the use of supplemental limits. The following five criteria are used to evaluate each application of supplemental limits:

- Where remedial action would pose a clear and present risk of injury to workers or members of the public, notwithstanding reasonable measures to avoid or reduce risk.

- Where remedial action, even after all reasonable mitigative measures have been taken, would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected properties, now or in the future.

- Where it is determined that the scenarios or assumptions used to establish the authorized limits do not apply to the property or portion of the property identified, or where more appropriate scenarios or assumptions indicate that other limits are applicable or appropriate for protection of the public and the environment.

- Where the cost of remedial action for contaminated soil is unreasonably high relative to long-term benefits and where the residual material does not pose a clear present or future risk after necessary control measures are taken. Remedial action will generally not be necessary where only minor quantities of residual radioactive material are involved or where residual radioactive material occurs in an inaccessible location at which specific property factors limit its hazard and from which it is difficult or costly to remove.

- Where there is no feasible remedial action.

For Building 14, the application of supplemental limits was determined on a case-by-case basis and implemented only after careful consideration of the above criteria. Each proposed application of supplemental limits is discussed in detail in the section of the PRAR related to the area for which it is proposed and the locations are summarized in Section 5. The development of the supplemental limits for the Building 14 interior is discussed in Section 1.4.

1.3.4 Implementation of ALARA Process

ALARA (as low as reasonably achievable) is a well-established approach used to manage and control exposure and releases of radioactive material to the environment so that levels are as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. In remedial action or decontamination and decommissioning work under DOE Order 5400.5, the concentration limit, or "guideline," for a particular radionuclide in soil or on surfaces is derived from the basic dose limit by using site-specific pathway analysis as a starting point, or "base case," for applying the ALARA process. In applying the ALARA process, the first task is to ensure that the area being remediated is at or below the authorized limit or dose constraint; the second is to determine that the residual radioactive material is reduced to levels that are as low as reasonably achievable below the dose constraint. This approach was applied during each phase of delineation and remediation conducted at Building 14.

1.4 DOSE ASSESSMENT CALCULATIONS IN SUPPORT OF SUPPLEMENTAL LIMITS

As discussed in Section 1.3.3, DOE Order 5400.5 provides for the release of property without radiological restrictions in cases where residual radioactive material may exceed established generic guidelines but does not pose a significant present or future exposure risk, and where the cost of remedial action is unreasonably high relative to long-term benefits. Further, DOE Order 5400.5 describes that remedial actions will generally not be necessary where only minor quantities of residual radioactive material are involved or where residual radioactive material occurs in an inaccessible location at which specific property factors limit its hazard and from which it is difficult or costly to remove. Examples include residual radioactive material under hard-surfaced public roads and sidewalks, around public sewer lines, or in fence-post foundations. A specific property analysis (which includes a dose exposure assessment) is required to demonstrate that the residual radioactive material would not cause an individual to receive a radiation dose in excess of the basic dose limits of 100 mrem/year under “actual” or “likely use” conditions. These dose exposure assessments and consideration of specific property factors establish the basis for the application of supplemental limits at the Linde Site.

Prior to the initiation of remedial efforts in Building 14, it became apparent that it would be difficult to attain generic release criteria because of site-specific conditions and that supplemental limits might need to be implemented in selected areas. Preliminary characterization data indicated that some residual contamination was present in areas inaccessible to current remedial technologies. Remediation of these areas (if possible) would be prohibitively expensive, would require expensive demolition of existing building structures, and would significantly disrupt facility operations. In addition, tenant activities at some locations within Building 14 were considered critical to the Praxair facility and could not be shut down for prolonged periods to facilitate a major decontamination effort. Therefore, it was necessary to develop baseline dose exposure information to allow an evaluation of the alternative supplemental limits on a case-by-case basis. This information, combined with engineering assessments of feasibility, cost estimates to perform remediation, and evaluation of health and safety concerns, was used to determine the appropriateness of the supplemental limits at each area where such difficulties were encountered.

Two exposure assessments were performed to determine the dose associated with current (“actual”) and future (“likely use”) building activities, including hypothetical renovation and building demolition scenarios. The first calculation (129-CV-023) estimated dose from exposure to residual contamination in the building floors, walls, and overheads. A second calculation (129-CV-029) was added when it was found that drainlines beneath the building may be contaminated. This calculation estimated dose from exposure to residual contamination in the in-bed drainlines during maintenance and remediation/demolition activities.

The dose assessment calculations were performed using computer modeling programs developed by DOE for determining allowable residual concentrations of radionuclides in soil (RESRAD, version 5.61) and evaluating the potential radiological dose incurred by an individual who works or lives in a building contaminated with radioactive material (RESRAD-BUILD, version 1.5). In this application, RESRAD and RESRAD-BUILD models accounted for exposure from three significant exposure pathways: direct external radiation exposure, internal dose from inhalation of airborne radionuclides, and internal dose from ingestion of contaminated soil. Preliminary characterization data from surveys taken prior to any remediation were used as input contamination levels for the baseline calculations. The derivation of these initial levels is discussed further for each calculation.

1.4.1 Development of Calculation 129-CV-023

This section discusses the scenarios, receptors, and data associated with Calculation 129-CV-023 and presents the results based on the described hypothetical exposures.

1.4.1.1 Scenarios

Four possible scenarios were evaluated to assess dose from exposure to residual contamination in the building floors, walls, and overheads: (1) “Typical Operations” to assess current working conditions within the building; (2) “Wall Renovation”; (3) “Footer Installation” to assess exposure from building renovation (“betterment”) activities; and (4) “Building Demolition” to assess exposure from complete building dismantlement and disposal. These scenarios are described in greater detail below.

The “Typical Operations” scenario (Scenario #1) is intended to represent annual exposure to a hypothetical worker from current non-intrusive activities and in every subsequent year until 50 years into the future. This scenario is consistent with the research and development activities presently being conducted at Building 14. Exposure under this scenario would result from the direct contact with accessible areas of contamination, inhalation of contaminated dust, and incidental ingestion of dust. The 50-year estimate is considered conservative because the estimated remaining lifespan of the building is approximately 25 years.

The “Wall Renovation” scenario (Scenario #2) represents exposure associated with demolition of a contaminated internal wall. For this scenario, it is assumed that the masonry materials are removed, crushed, and disposed of in a landfill. The steel is removed, cut, recycled at a smelter, and then the slag is used as roadbed material. Pathways included in this scenario are inhalation, ingestion, and direct exposure.

The “Footer Installation” scenario (Scenario #3) represents exposure from the removal of a contaminated section of floor and subslab soil to install an equipment footer. In this scenario, the concrete is crushed and the removed material is disposed of in a landfill. Exposure pathways are similar to Scenario #2.

The “Demolition” scenario (Scenario #4) represents exposure associated with the total dismantlement and disposal of Building 14. The scenario includes masonry demolition, metal demolition, masonry crushing, metal recycling, and disposal of masonry and metal slag. These activities are assumed to occur in separate phases, which is considered conservative because the likely scenario would entail rapid mechanical destruction of the structure and subsequent removal of debris. Exposure pathways are similar to Scenario #2.

1.4.1.2 Receptors

In each scenario, up to four receptors were considered based on their possible likelihood for exposure: (1) On-Site worker, (2) Steel Recycling Worker, (3) Landfill Worker, and (4) Commuter. The On-Site worker, present in all scenarios, represented the receptor most likely to be exposed: the worker in the building during normal operations in Scenario #1, or the worker directly performing the building renovations or demolition activities in Scenarios #2, #3, and #4. The Steel Recycling Worker was considered under the assumption that metal removed during renovation and demolition activities (Scenarios #2 and #4) would be recycled. The Landfill Worker was considered under the assumption that non-recyclable material and soil generated during Scenarios #2, #3, and #4 would be disposed of in a landfill. Finally, the Commuter was evaluated under the assumption that metal recycling slag would be used as roadbed material (Scenarios #2 and #4). The exposure parameters for each of the receptors in the various scenarios are presented in Table 1-3.

1.4.1.3 Exposure Data

Preliminary characterization data, obtained prior to any remedial activity, were used as the initial levels of contamination in the four scenarios. Survey data had been collected from most areas of the building (approximately 77 percent). The survey readings were averaged for each building component surface (i.e., walls, floors, and overhead structures) to determine representative levels. In order to obtain conservative estimates of exposure and to offset any uncertainty due to the unsurveyed areas, only those measurements above DOE Order 5400.5 guidelines were used to determine the average levels (i.e., readings below 5,000 dpm/100 cm^2 were removed from the calculation). This resulted in a high-biased data set. The assumed average level of contamination for each building component is shown in Table 1-4.

1.4.1.4 Results

The results of Calculation 129-CV-023 are presented in Table 1-5. As shown, the annual dose ranges from 0.003 to 8.39 mrem/year. These doses correspond to contamination levels shown in Table 1-4. The maximum dose is received by the On-Site Worker performing building demolition activities under Scenario #4. Building surfaces with lower levels of contamination would be expected to result in lower levels of dose exposure.

1.4.2 Development of Calculation 129-CV-029

During the course of remedial activities in Building 14, the in-bed drainlines (which are located beneath the foundation of the building) were found to contain residual contamination above the generic release criteria. Most of the lines are inaccessible, and those sections that are accessible have been previously filled with grout. Based on the prohibitive costs associated with remediating these lines, a dose assessment calculation was performed to determine the dose associated with the residual contamination. This section discusses the scenarios, receptors, and data associated with Calculation 129-CV-029 and presents the results based on the described hypothetical exposures.

1.4.2.1 Scenarios

Two possible scenarios were evaluated to assess dose from exposure to residual contamination in the in-bed drainlines. Because it was unknown how much of the total length of drainline had been filled with grout, Calculation 129-CV-023 evaluated a scenario in which the sections with observed grout were assumed to be entirely filled (Scenario #1) and a scenario which assumed no grout fill in any of the drainline sections (Scenario #2). The presence of grout in the drainline would encapsulate the residual radioactive contamination (believed to exist as scale on the interior walls of the pipe) which would significantly reduce the source term. Since this assumption is critical in determining the hypothetical dose, the two scenarios are intended to provide a conservative range of possible dose exposures as a result of this uncertainty.

1.4.2.2 Receptors

In each scenario, two receptors were considered based on their possible likelihood for exposure: (1) Non-Routine Maintenance Worker and (2) Renovation Worker. The Non-Routine Maintenance Worker represents short-term intrusive work activities inside the drainlines (e.g., clearing blocked drainlines). The Renovation Worker provides an upper bound estimate of potential future worker exposure in that the worker may be exposed during removal of the in-bed drainlines during major renovation activity. In this case, the exposure duration is longer due to the nature of the work. Both receptors are exposed through ingestion of contaminated material, inhalation of contaminated dust, and direct exposure to external γ radiation. The exposure parameters for each of the receptors in the various scenarios are presented in Table 1-6.

1.4.2.3 Exposure Data

The in-bed drainlines consist of five sections (Sections A through E). The three shorter sections (Sections A, B, and E) are associated with the remediated sumps/tanks. Measurements obtained from these sections were assumed to be representative of the adjacent, inaccessible sections (Sections C and D). These estimates were considered to be conservative since only the maximum levels from each of the measured sections were used as the representative levels. The assumed average level of contamination for each section, shown in Table 1-4, ranges from 19,900 to 140,000 dpm/100 cm^2.

1.4.2.4 Results

The results of Calculation 129-CV-029 are presented in Tables 1-7 and 1-8 for Scenarios #1 and #2, respectively. Contributions of dose from individual sections of drainline are also shown. Total annual dose from exposure to residual contamination in all sections of the in-bed drainline ranges from 1.27 to 15.3 mrem/year. The maximum dose is received by the Renovation Worker under Scenario #2, which assumed no fill in any of the drainlines. It should be noted that this scenario does not reflect realistic conditions because it is known that some portions of the drainlines are filled. Exposure to residual contamination in other drainlines with lower levels of contamination would be expected to result in lower dose exposure levels.

Table 1-1

Summary of Remedial Criteria and Guidelines

Contaminated Media	Radionuclides	Remedial Criteria
Surface[a,b] Average Total Activity per m^2	Natural uranium[c] and beta-gamma emitters[d]	5,000 dpm/100 cm^2
Surface[a,e,f] Maximum Total Activity in 100 cm^2	Natural uranium[c] and beta-gamma emitters[d]	15,000 dpm/100 cm^2
Surface[a,e] Removable Activity	Natural uranium[c] and beta-gamma emitters[d]	1,000 dpm/100 cm^2
Soil[g, h]	Radium-226 and Thorium-230[i]	5 pCi/g in excess of background averaged over the first 15 cm layer of soil below the surface and 15 pCi/g in excess of background averaged over 15 cm thick layers of soil more than 15 cm below the surface.
Soil[h]	Total uranium	60 pCi/g above background levels for any 15 cm layer of soil

Abbreviations:

cm	centimeter
dpm	disintegrations per minute
h	hour
m	meter
mrad	milli-radiation dose absorbed
pCi/g	picocuries per gram

Notes:

a Criteria from DOE Order 5400.5, Ch. IV, Sec. 4 (d). 8 February 1990.

b Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

c Criteria also apply to uranium-238, uranium-238, and associated decay products and alpha emitters.

d Includes beta-gamma emitters with the exception of strontium-90 and others as noted in DOE Order 5400.5, Ch. IV, Sec. 4 (d), Figure IV-1.

e The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

f The maximum contamination level applies to an area of not more than 100 cm^2.

g Criteria from DOE Order 5400.5, Ch. IV, Sec. 4 (a) (2). 8 February 1990.

h Criteria from Memorandum from James W. Wagoner II to Lester K. Price, Department of Energy, *Uranium Guidelines for the Tonawanda Sites*. PDCC No. 087978. 8 April 1992.

i The reference in Note e applies this criteria to radium-226, radium-228, thorium-230, and thorium-232. The reference in Note f above includes radium-226 and thorium-230 but does not mention radium-228 and thorium-232.

Table 1-2

Background Concentrations of Radionuclides in Soil[a]

Radionuclide	Range (pCi/g)	Mean (pCi/g)	Standard Deviation (pCi/g)
Uranium-238	2.0 to 4.0	3.1	0.6
Radium-226	1.0 to 1.6	1.1	0.2
Thorium-230	1.1 to 1.8	1.4	0.3
Thorium-232	1.0 to 1.6	1.2	0.3

Abbreviation:

pCi/g   picocuries per gram

Note:

a   Background concentrations established in the Remedial Investigation Report for the Tonawanda Site (DOE 1993).

Table 1-3

Summary of Exposure Parameters for Calculation 129-CV-023

Exposure Parameter	On-Site Worker	Steel Recycling Worker	Landfill Worker	Commuter
Exposure Frequency	8 hr/day	8 hr/day	4 hr/day	10 min/day
Exposure Duration	250 days (Scenario #1)	0.5 days (Scenario #2)	250 days	250 days
	28.5 days (Scenario #2)	24.6 days (Scenario #4)		
	2.5 days (Scenario #3)			
	327 days (Scenario #4)			
Inhalation Rate	2.5 m^3/hr	2.5 m^3/hr	NA[1]	NA[2]
Ingestion Rate	480 mg/day	480 mg/day	NA[1]	NA[2]

Abbreviations:
hr hour
m^3 cubic meter
mg milligram

Notes:

[1]For Landfill worker, only the external exposure pathway is analyzed because the cover material must be maintained at all times. Therefore, the rubble and soil are not available for the inhalation or ingestion pathways.

[2]For the Commuter, only the external exposure pathway is analyzed because the material is not available for inhalation or ingestion. The metal slag is incorporated into the subbase as a solid mass and is covered with 0.15 m of gravel and asphalt.

Table 1-4

Assumed Levels of Average Residual Radioactive Contamination for Calculation 129-CV-023 and 129-CV-029

Building Component	Calculation	Assumed Average Level of Contamination (dpm/100 cm^2)
Floors	129-CV-023	24,976
Walls	129-CV-023	19,006
Overheads (Structural Steel)	129-CV-023	24,851-26,888
Overheads (Pipes and Conduits)	129-CV-023	24851-19,355
Overheads (Ducts)	129-CV-023	4,154
In-Bed Drainline (Section A)	129-CV-029	140,000
In-Bed Drainline (Section B)	129-CV-029	80,000
In-Bed Drainline (Section C)	129-CV-029	80,000
In-Bed Drainline (Section D)	129-CV-029	80,000
In-Bed Drainline (Section E)	129-CV-029	19,900

Abbreviation:
dpm/100 cm^2 disintegrations per 100 square centimeters

Table 1-5

Results of Dose Assessment Calculation for Floors, Walls, and Overheads (Calculation 129-CV-023)

Exposure Scenario	On-Site Worker (mrem/yr)	Steel Recycling Worker (mrem/yr)	Landfill Worker (mrem/yr)	Commuter (mrem/yr)
Typical Operations	4.82-5.82	NA	NA	NA
Wall Renovation	1.22	0.47	0.03	0.003
Footer Installation	2.11	NA	0.69	NA
Building Demolition	8.39	0.78	0.015	0.003

Abbreviations:
mrem millirems
yr year

Table 1-6

Summary of Exposure Parameters for Calculation 129-CV-029

Exposure Parameter	Non-Routine Maintenance Worker	Renovation Worker
Exposure Frequency	10 hrs/day	10 hrs/day
Exposure Duration	2 days	10 days
Inhalation Rate	0.89 m^3/hr	0.89 m^3/hr
Ingestion Rate	100 mg/day	100 mg/day

Abbreviations:
hrs hours
m^3 cubic meter
mg milligram

Table 1-7

Results of Dose Assessment Calculation for In-Bed Drainlines - Scenario #1 (Calculation 129-CV-029)

Drainline Section	Non-Routine Maintenance Worker (mrem/yr)	Renovation Worker (mrem/yr)
Section A	0.03	0.1
Section B	0.01	0.1
Section C	0.61	3.1
Section D	0.61	3.1
Section E	0.00	0.0
Total Dose	1.27	6.4

Abbreviations:
mrem millirems
yr year

Table 1-8

Results of Dose Assessment Calculation for In-Bed Drainlines - Scenario #2 (Calculation 129-CV-029)

Drainline Section	Non-Routine Maintenance Worker (mrem/yr)	Renovation Worker (mrem/yr)
Section A	1.07	5.4
Section B	0.61	3.1
Section C	0.61	3.1
Section D	0.61	3.1
Section E	0.16	0.8
Total Dose	3.07	15.3

Abbreviations:
mrem millirems
yr year